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RESEARCH MEMORANDUM

TIME HISTORIES OF THE AERODYNAMIC LOADS ON THE VERTICAL AND HORIZONTAL TAIL SURFACES OF A JET-POWERED BOMBER AIRPLANE DURING SIDESLIP MANEUVERS AT APPROXIMATELY 20,000 FEET

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CLASSIFICATION CANCELLED

Authority NACA R7 2607 Date 8/31/54

By 9/15/54 See

CLASSIFICATION CHANGED

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RESEARCH MEMORANDUM

TIME HISTORIES OF THE AERODYNAMIC LOADS ON THE VERTICAL AND HORIZONTAL TAIL SURFACES OF A JET-POWERED BOMBER AIRPLANE DURING SIDESLIP MANEUVERS AT APPROXIMATELY 20,000 FEET

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SUMMARY

Time histories are presented of the aerodynamic loads on the vertical and horizontal tail surfaces of a jet-powered bomber airplane (B-45A) in sideslip maneuvers. The data were obtained at a pressure altitude of approximately 20,000 feet in the Mach number range from 0.31 to 0.76. The maximum measured rudder and fin loads were 1,800 pounds and 2,830 pounds, respectively, and the maximum total vertical-tail load was 1,120 pounds. The greatest horizontal-tail-load dissymmetry was 3,280 pounds. The maximum elevator loads measured were 340 pounds down and 680 pounds up. Both values occurred on the left elevator. In trim level flight an elevator-load dissymmetry as great as 420 pounds occurred. The greatest change in elevator-load dissymmetry with sideslip was 260 pounds.

INTRODUCTION

The National Advisory Committee for Aeronautics is currently undertaking a flight investigation to determine the tail loads and deformations on a jet-bomber airplane. The aims of this investigation are to obtain basic aerodynamic parameters from flight data for comparison with small-scale wind-tunnel results and to study the effects of aeroelasticity on the distribution of the horizontal-tail load and on the longitudinal stability of the airplane. For this investigation a B-45A airplane has been instrumented with strain-gage bridges for the measurements of the loads on the vertical tail, horizontal tail, and wing and with additional instruments for the measurements of the elevator and stabilizer twist and the fuselage deflection.

As the various phases of the flight-investigation are completed, data are reported in time-history form. No analysis of the results will be made until the flight program has been completed.

Time histories of the aerodynamic loads and deformations for the B-45A airplane during level flight, aileron rolls, abrupt pull-ups, and gradual turns have been presented in references 1 to 6. Presented in this paper are time histories of the vertical- and horizontal-tail loads obtained during maneuvers which approximated steady sideslipping conditions. The maneuvers were made at a pressure altitude of approximately 20,000 feet and covered a Mach number range from 0.31 to 0.76.

The data were obtained with a modified configuration of the original B-45A airplane. The modification consisted of installing reflex wing flaps, rigging the ailerons up, and adding positive twist by warping the tips of the horizontal-tail leading edge up. A comparison of the horizontal-tail loads resulting from 1 g trim level flight for the present configuration airplane and for the original configuration airplane is also presented.

SYMBOLS

M	Mach number
C_{N_A}	airplane normal-force coefficient (nW/qS)
q	dynamic pressure, pounds per square foot
n	normal acceleration at airplane center of gravity, g units
W	airplane weight, pounds
S	wing area, square feet
L_{H_L}	horizontal-tail load, left side, pounds
L_{H_R}	horizontal-tail load, right side, pounds
$L_{H_L} - L_{H_R}$	horizontal-tail-load dissymmetry, pounds
L_V	vertical-tail total load, pounds

L_F fin load, pounds

L_R rudder load, pounds

β sideslip angle (sideslip to the right is positive), degrees

With the foregoing symbols, the prefix Δ represents an increment measured from the trim value.

Up loads on the horizontal stabilizers and elevators are considered positive. Positive loads on the vertical tail act to the right. Other sign conventions used are defined in the figures.

INSTRUMENTATION

A three-view drawing of the test airplane, with the approximate locations of the strain-gage bridges and deflection-measuring devices, is given in figure 1.

Standard NACA recording instruments were used to measure airspeed and altitude, rolling, pitching, and yawing velocities, sideslip angle, angle of bank, control forces and positions, and accelerations. NACA three-component accelerometers were mounted at the airplane center of gravity and at the approximate quarter-chord station of the horizontal tail at the airplane center line.

The airspeed head and sideslip-angle transmitter were located on booms, at the tip of the left and right wings, respectively, and extended approximately 1 local chord length ahead of the leading edge. The results of a flight calibration of the airspeed system for position error and an analysis of available data for a similar installation indicated a Mach number error of less than ± 0.01 throughout the test range. Sideslip-angle measurements presented are the measured values and have not been corrected for effects of inflow at the boom location. Electrical resistance strain-gage bridges were mounted on each spar near the root of both the horizontal and vertical tail surfaces to measure shear and bending moment. Strain-gage bridges were also mounted on the elevator and rudder torque tubes and hinge brackets to measure torque and control-surface total loads.

Twist bars were installed in the horizontal stabilizers to measure the twist of the midsemispan and tip with respect to the stabilizer root. Control-position transmitters were installed at the tip and root of each elevator to measure twist of the elevator relative to the stabilizer. The positions of the rudder, ailerons, elevators, and elevator spring-loaded tabs were measured at the inboard ends of each surface by control-position transmitters.

The output from the strain-gage bridges and twist-measuring devices was recorded on two 18-channel oscillographs. A 0.1-second time pulse was used to correlate the records of all recording instruments.

RESULTS AND DISCUSSION

Aerodynamic loads on the vertical and horizontal tail surfaces were determined for the B-45A airplane during maneuvers made by gradually increasing the sideslip angle in nonturning flight. Nearly steady side-slipping conditions were considered to prevail since the rate of change to sideslip angle was in general less than $\frac{1}{2}^{\circ}$ per second. The airplane was in the clean condition and in trim steady flight at the start of each maneuver. In all runs the pilot continued to increase the sideslip angle until full rudder pedal travel or limiting pedal force prevented further increases. The maximum measured loads are therefore the greatest obtainable by the test pilot for this airplane in the type of maneuver considered.

Time histories of the aerodynamic loads, control positions, and measured sideslip angle are presented in figures 2 to 15. Information pertaining to the flight conditions existing during each maneuver illustrated in the time histories is summarized in table I.

Aerodynamic loads were obtained by the addition of the net structure loads, from the strain-gage measurements, and the inertia loads which were computed from the accelerations measured at the tail.

The quantities presented in this paper are estimated to be accurate to within the following amounts:

Mach number	±0.01
Sideslip angle (uncorrected for inflow), deg	±0.10
Total horizontal-tail aerodynamic load, lb	±160
Elevator aerodynamic load, lb	±60
Elevator position, deg	±0.05
Rudder aerodynamic load, lb	±30
Rudder position, deg	±0.25
Fin aerodynamic load, lb	±100
Total vertical-tail load, lb	±130

Vertical-tail loads.- The maximum fin load measured, 2,830 pounds, occurred with a measured sideslip angle of 3.5° to the right during the run (fig. 13; time, 34 sec) made at a Mach number of 0.70. The maximum rudder load measured (fig. 14) was 1,800 pounds and occurred with a rudder deflection of 8.9° to the left and a sideslip angle of 2.7° to the right at a Mach number of 0.74. The maximum total vertical-tail load of 1,120 pounds to the left (fig. 13; time, 30 sec) resulted from a fin load of 2,770 pounds to the left and a rudder load of 1,650 pounds to the right.

The Mach number for the condition giving maximum vertical-tail load was 0.70 and the rudder position and sideslip angle were 9.2° left and 3.2° right, respectively.

The variation with increment in sideslip angle of the increment in fin, rudder, and total vertical-tail load per unit dynamic pressure for a typical run ($M = 0.45$; $C_{N_A} = 0.39$) is shown in figure 16. The variation with sideslip angle of the total vertical-tail load given in this figure was obtained from the curves which had been faired through the measured values of fin and rudder load per q. The variations with $\Delta\beta$ of the total vertical-tail load per q shown in figure 17 for the various Mach numbers and airplane normal-force coefficients were obtained in the manner indicated in figure 16. The curves for $M = 0.31$ and $M = 0.35$ have been omitted from figure 17 because their significance was obscured by the accuracy range of total vertical-tail load per q for the low values of q. The slope of the curves $\frac{\Delta L_V}{q}\Big/\Delta\beta$ is a measure of the unstable yawing moment of the wing-fuselage combination.

<u>Horizontal-tail-load dissymmetry</u>.- The maximum horizontal-tail-load dissymmetry recorded (fig. 4) was 3,280 pounds and occurred with 14.3° measured sideslip to the left at $M = 0.35$. The variation with incremental sideslip angle of the horizontal-tail-load dissymmetry per unit dynamic pressure is shown in figure 18 for two representative maneuvers. It can be seen that the horizontal-tail-load dissymmetry varies linearly with sideslip angle to the maximum sideslip angle reached. Similar plots have been made for all the maneuvers and the slopes $\frac{\Delta\left(L_{H_L} - L_{H_R}\right)}{q}\Big/\Delta\beta$ obtained have been entered in table I. As indicated in table I, there is a slight increase in slope with Mach number up to $M = 0.40$ and then a general decrease. It can also be noted that the slope is greater in left sideslips than in right sideslips at the same Mach number and airplane normal-force coefficient.

<u>Total horizontal-tail loads</u>.- The maximum up tail load measured during sideslips was 3,100 pounds at a Mach number of 0.35 and a sideslip angle of 14.3° to the left. The maximum down tail load measured was 5,180 pounds at a Mach number of 0.76 and a sideslip angle of 1.6° to the right.

The change with Mach number of the horizontal-tail loads in 1g trim level flight is shown in figure 19. Also shown in figure 19 for comparison are the 1g loads obtained at 20,000 feet with the original configuration airplane.

A portion of the data shown in figure 19 for the original configuration airplane has been taken from the time histories presented in reference 6. The fact that more up tail load was required for level flight in the case of the modified configuration airplane indicates that the desired reduction of the zero-lift pitching-moment coefficient of the airplane was accomplished when the wing flaps were reflexed and the ailerons were rigged up.

Elevator loads.- In trim level flight the maximum measured down load on the left elevator was 340 pounds and occurred at $M = 0.31$ (fig. 2). The maximum measured up load on the left elevator, 680 pounds, occurred at $M = 0.74$ (fig. 14). The loads on the right elevator varied from 60 pounds up at $M = 0.35$ (fig. 4) to 560 pounds up at $M = 0.70$ (fig. 13). The maximum measured elevator-load dissymmetry in trim level flight was 420 pounds at $M = 0.35$ (fig. 4). The greatest change in elevator-load dissymmetry with sideslip was 260 pounds and was measured during the run made at $M = 0.51$ (fig. 8) with a sideslip angle of 8.3° to the right.

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2. Cooney, T. V., and McGowan, William A.: Time Histories of Loads and Deformations on a B-45A Airplane in Two Aileron Rolls. NACA RM L9I28a, 1949.

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TABLE I

SUMMARY OF FLIGHT CONDITIONS AND HORIZONTAL-TAIL-LOAD DISSYMMETRY CONSTANTS

Figure	Airplane weight (lb)	Center-of-gravity position (percent M.A.C.)	Mach number	Approximate q (lb/sq ft)	Pressure altitude (ft)	Airplane normal-force coefficient, C_{N_A}	Elevator-trim-tab position, positive for airplane nose up (deg)	Rudder-trim-tab position, airplane nose left (deg)	Sideslip-angle increment from trim, $\Delta\beta$	Power condition (percent maximum rpm)	$\frac{\Delta\left(L_{H_L} - L_{H_R}\right)/\Delta\beta}{q}$ $\left(\mathrm{ft}^2/\mathrm{deg}\right)$
2	65,100	28.6	0.31	65	19,900	0.86	13.5	1.2	12.6R	85	1.90
3	64,600	28.6	.35	84	20,100	.65	11.5	1.3	12.3R	87	2.17
4	64,300	28.5	.35	82	20,200	.66	11.5	1.3	13.6L	87	-2.65
5	63,900	28.5	.40	108	20,400	.50	8.8	1.3	10.3R	85	2.30
6	63,500	28.4	.45	140	20,200	.39	6.0	1.7	10.7R	87	2.02
7	63,200	28.4	.45	139	20,000	.39	6.0	1.7	6.8L	87	-2.34
8	62,700	28.3	.51	178	20,100	.30	4.1	1.3	9.7R	90	1.95
9	62,300	28.3	.56	214	20,300	.25	2.3	.5	7.5R	92	1.97
10	62,100	28.3	.55	207	20,300	.25	2.3	.5	3.2L	92	-2.50
11	61,600	28.2	.62	259	20,100	.20	.8	0	6.8R	94	1.75
12	62,300	28.0	.67	305	20,200	.17	-2.0	.5	5.8R	100	1.64
13	62,000	27.9	.70	337	19,600	.15	-2.1	.5	5.0R	100	1.72
14	61,000	27.8	.74	380	19,400	.13	-2.4	.5	4.2R	100	1.33
15	60,500	27.7	.76	406	18,200	.12	-2.5	.5	3.4R	100	1.33

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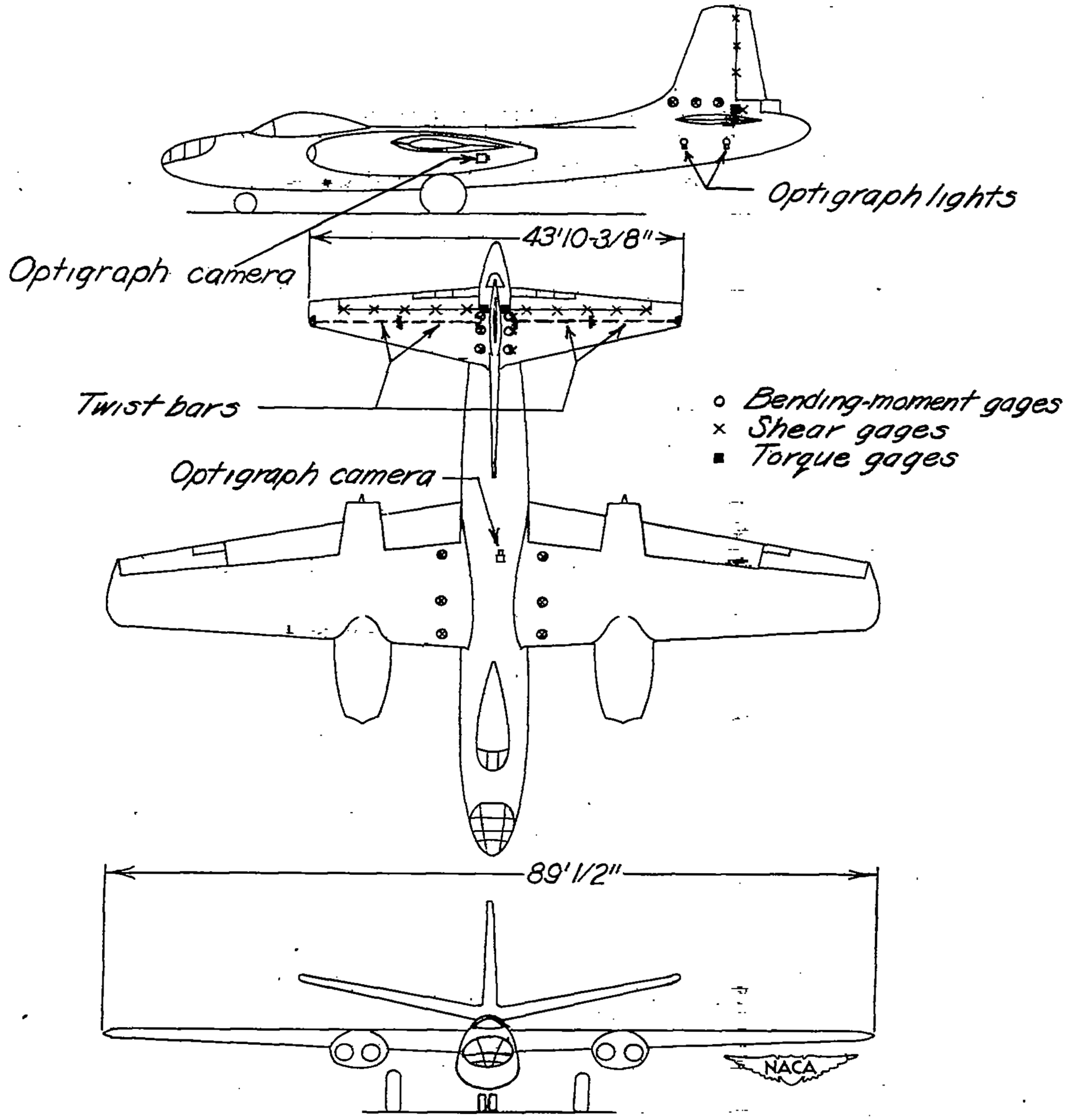

Figure 1.- Three-view drawing of test airplane showing approximate locations of strain-gage bridges and deflection measuring devices.

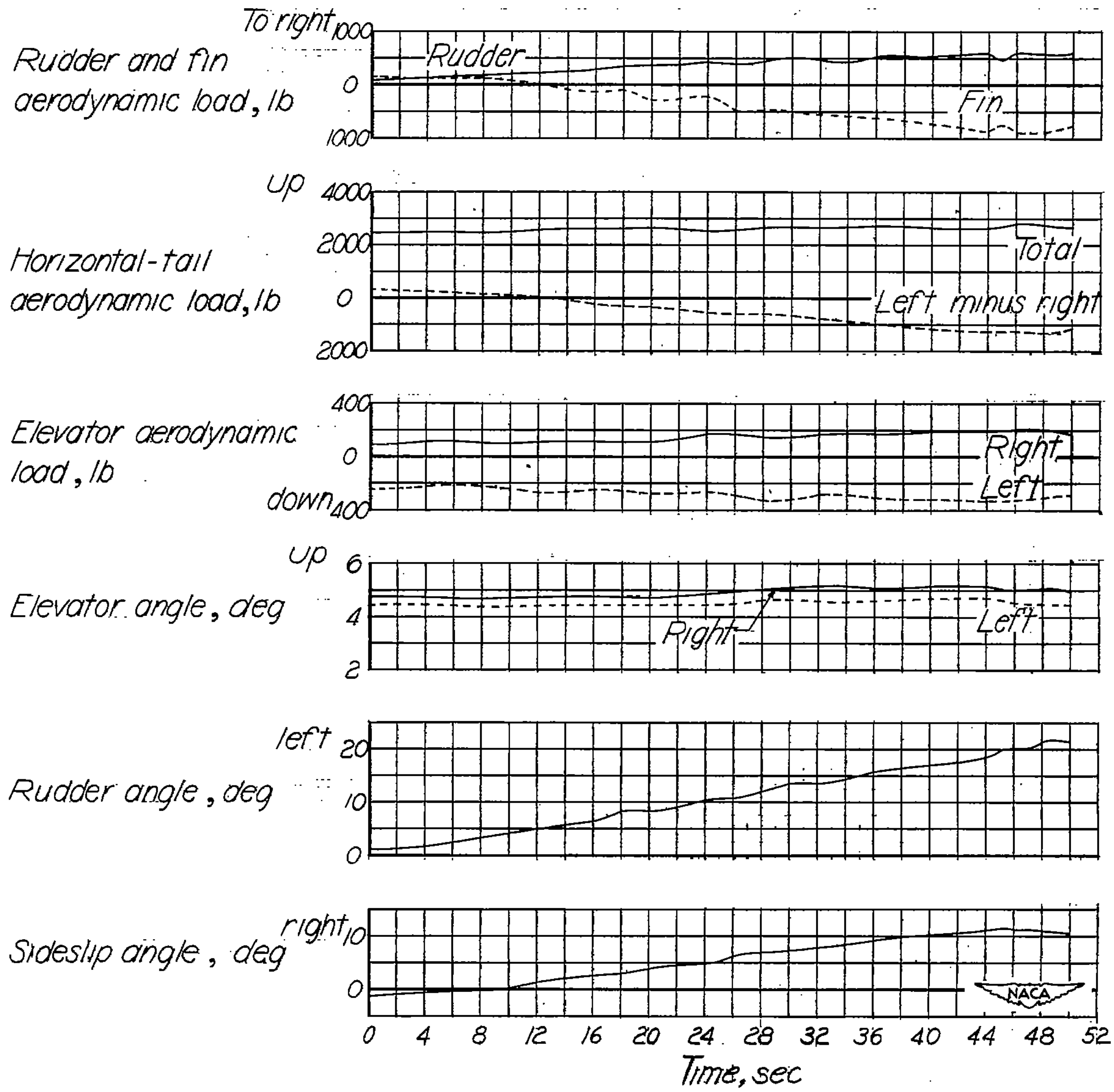

Figure 2.- Time histories of various quantities during a **right sideslip**. Pressure altitude, 19,900 feet; Mach number, 0.31; airplane weight, 65,100 pounds; center of gravity is at 28.6 percent mean aerodynamic chord; rudder trim tab, 1.2° airplane nose left; airplane normal-force coefficient, 0.86.

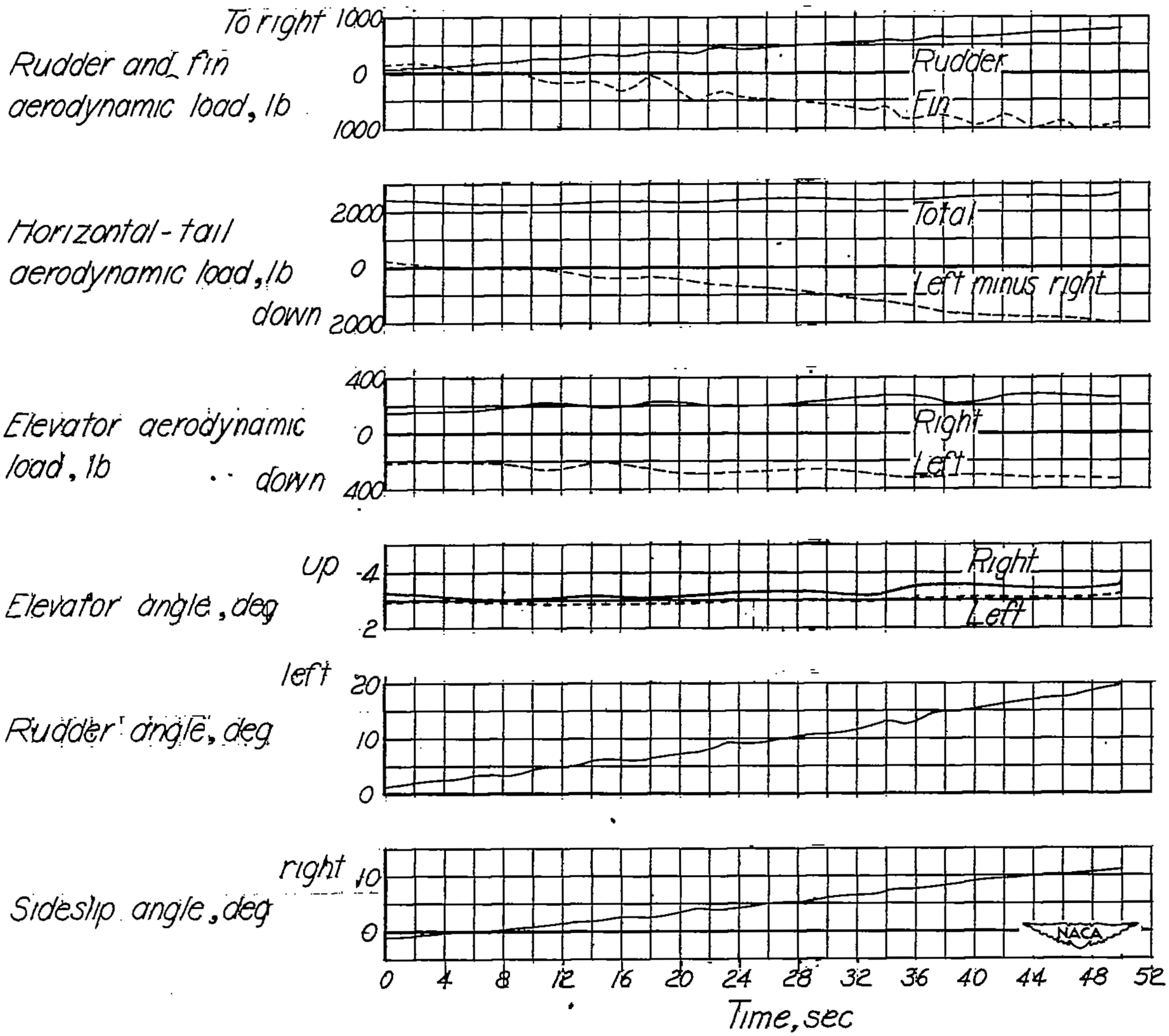

Figure 3.- Time histories of various quantities during a right sideslip. Pressure altitude, 20,100 feet; Mach number, 0.35; airplane weight, 64,600 pounds; center of gravity is at 28.6 percent mean aerodynamic chord; rudder trim tab, 1.3° airplane nose left; airplane normal-force coefficient, 0.65.

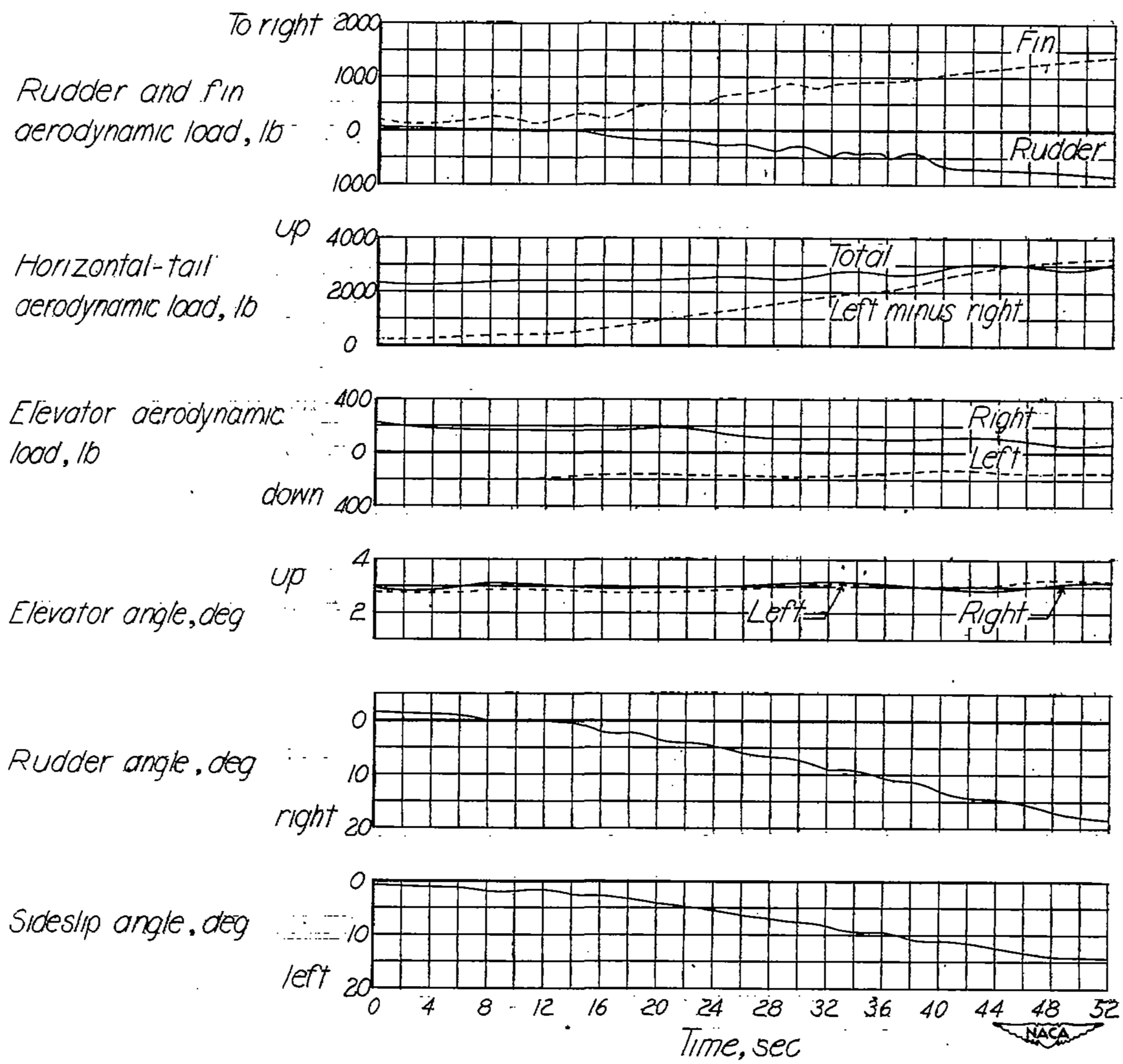

Figure 4.- Time histories of various quantities during a left sideslip. Pressure altitude, 20,200 feet; Mach number, 0.35; airplane weight, 64,300 pounds; center of gravity is at 28.5 percent mean aerodynamic chord; rudder trim tab, 1.3° airplane nose left; airplane normal-force coefficient, 0.66.

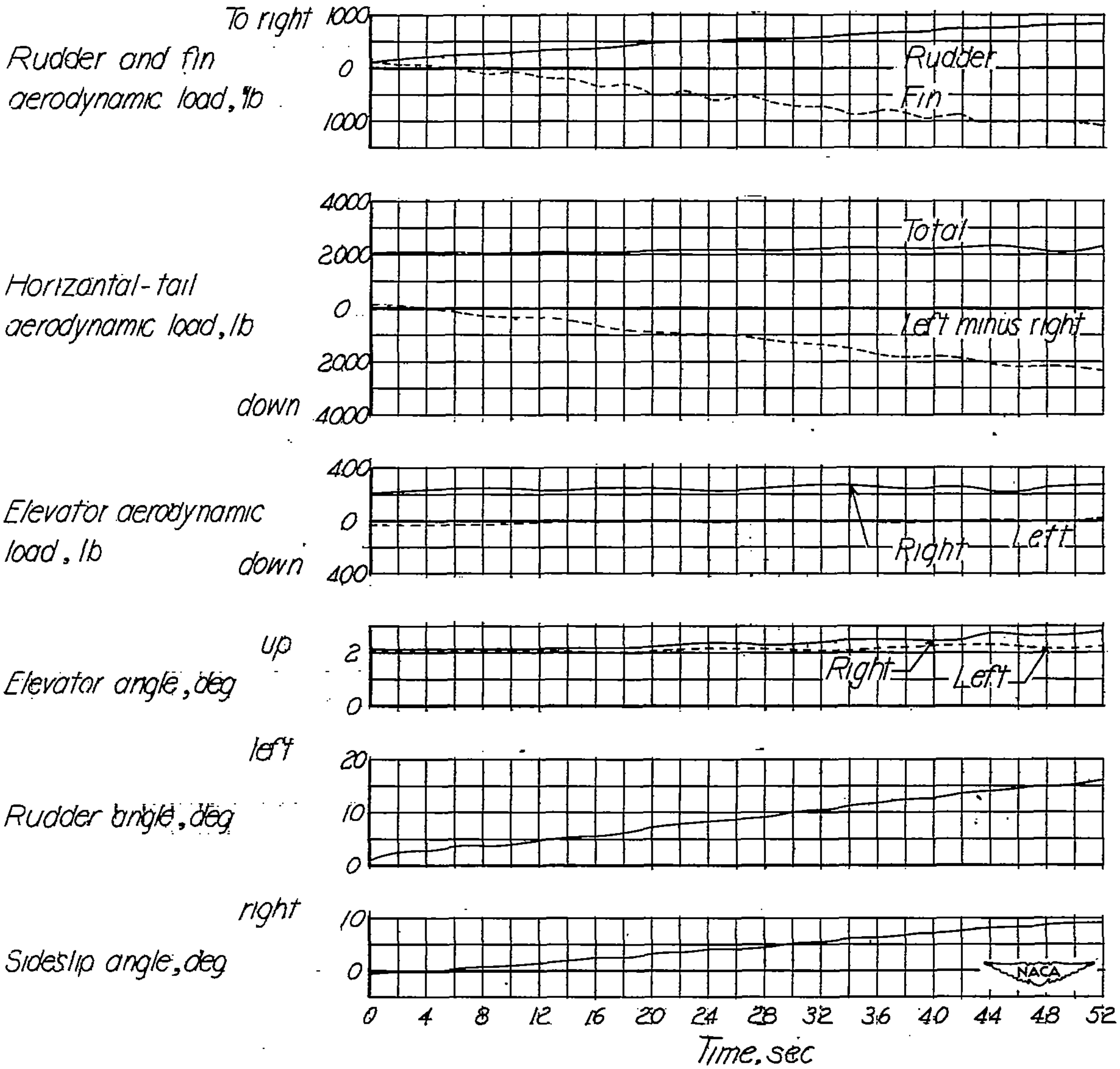

Figure 5.- Time histories of various quantities during a right sideslip. Pressure altitude, 20,400 feet; Mach number, 0.40; airplane weight, 63,900 pounds; center of gravity is at 28.5 percent mean aerodynamic chord; rudder trim tab, 1.3° airplane nose left; airplane normal-force coefficient, 0.50.

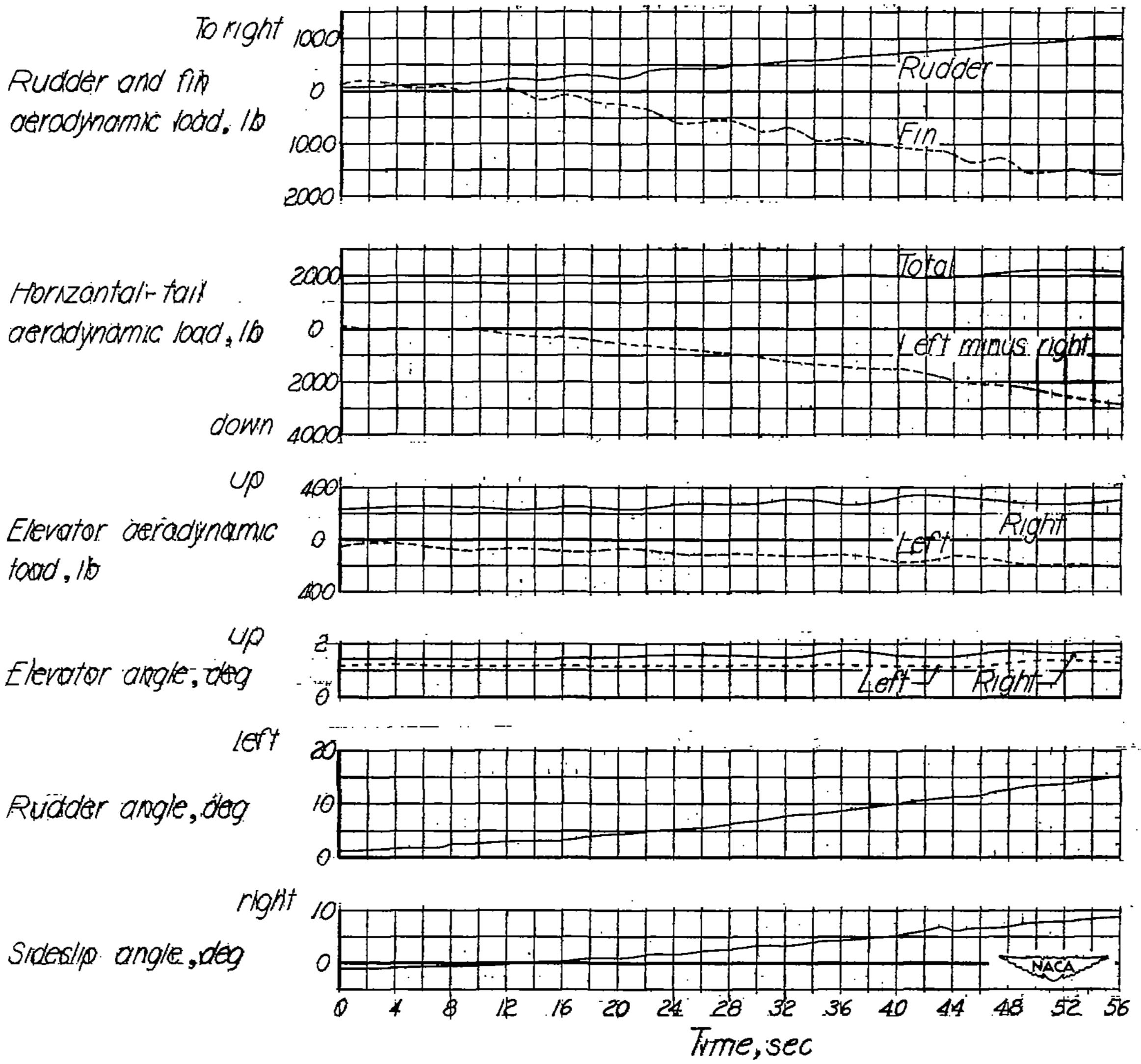

Figure 6.- Time histories of various quantities during a right sideslip. Pressure altitude, 20,200 feet; Mach number, 0.45; airplane weight, 63,500 pounds; center of gravity is at 28.4 percent mean aerodynamic chord; rudder trim tab, 1.7° airplane nose left; airplane normal-force coefficient, 0.39.

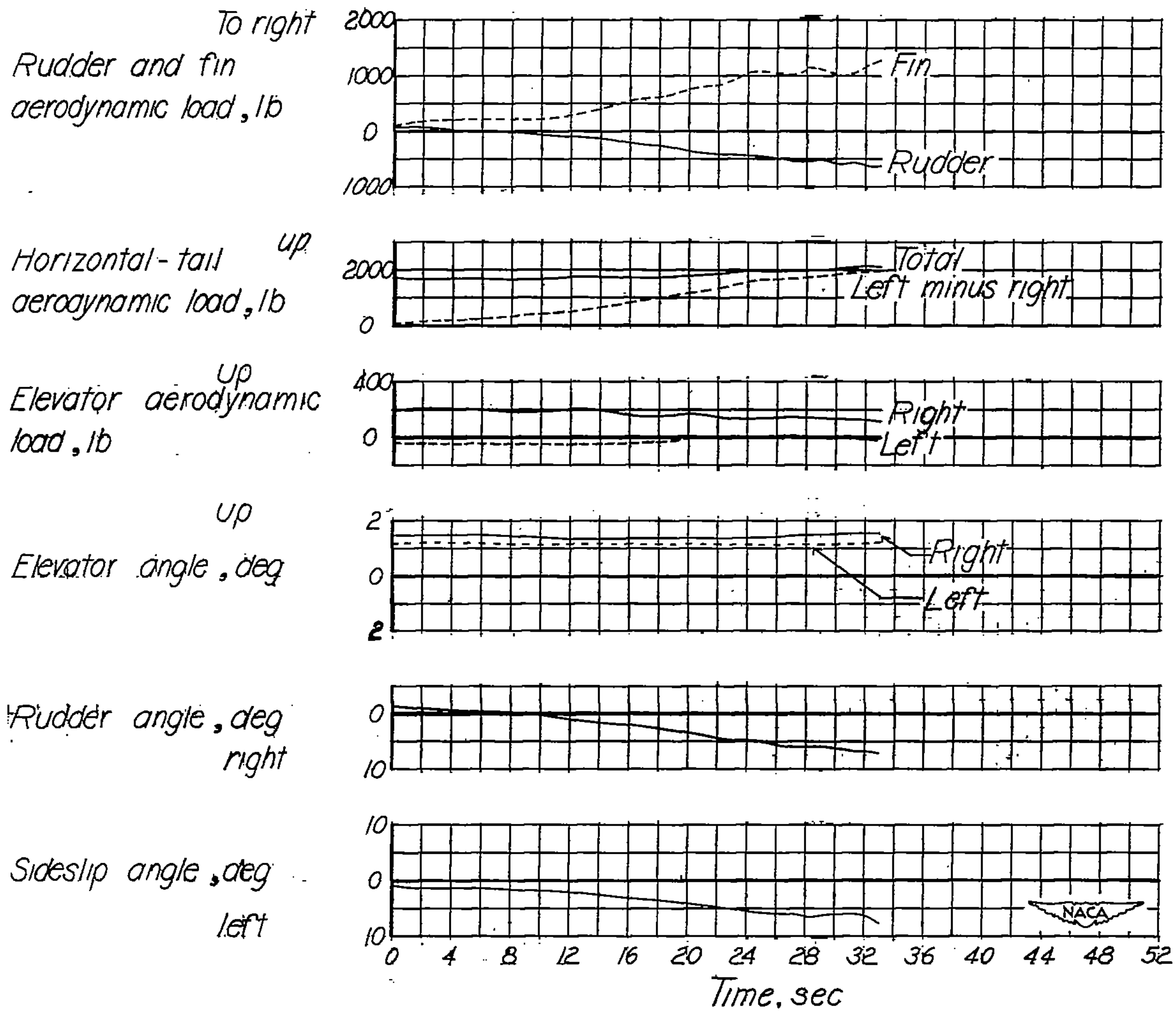

Figure 7.- Time histories of various quantities during a left sideslip. Pressure altitude, 20,000 feet; Mach number, 0.45; airplane weight, 63,200 pounds; center of gravity is at 28.4 percent mean aerodynamic chord; rudder trim tab, 1.7° airplane nose left; airplane normal-force coefficient, 0.39.

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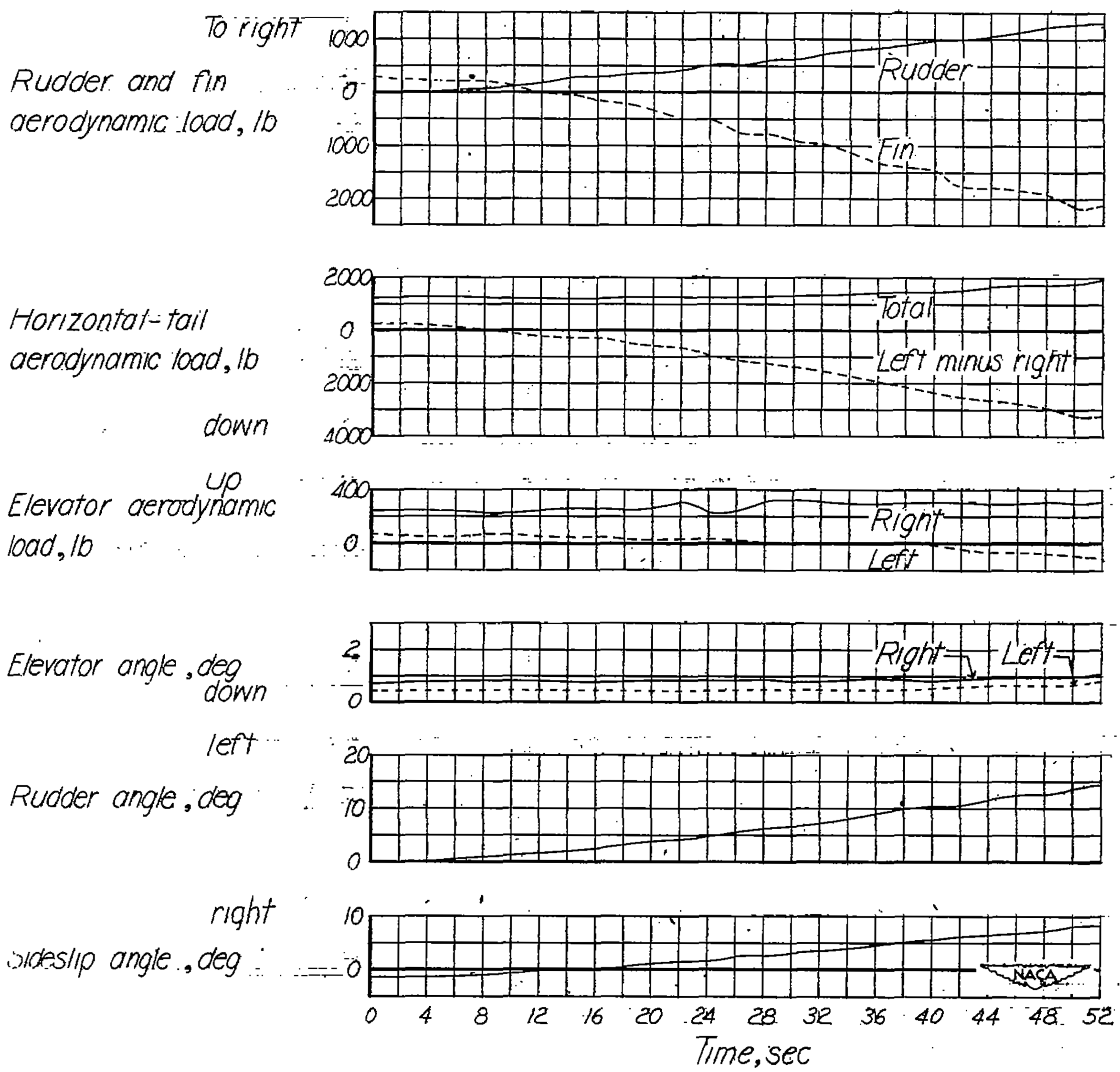

Figure 8.- Time histories of various quantities during a right sideslip. Pressure altitude, 20,100 feet; Mach number, 0.51; airplane weight, 62,700 pounds; center of gravity is at 28.3 percent mean aerodynamic chord; rudder trim tab, 1.3° airplane nose left; airplane normal-force coefficient, 0.30.

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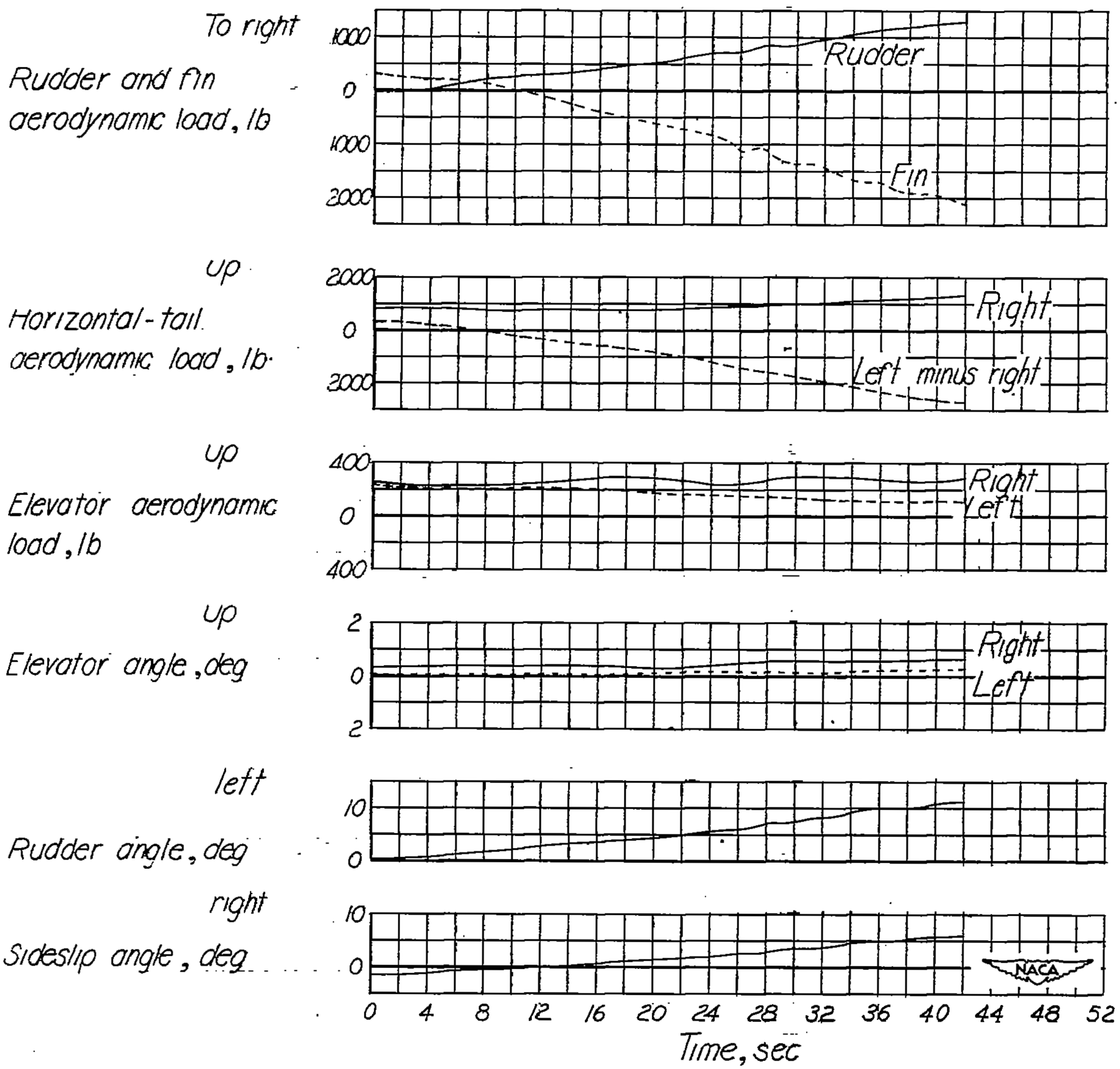

Figure 9.- Time histories of various quantities during a right sideslip. Pressure altitude, 20,300 feet; Mach number, 0.56; airplane weight, 62,300 pounds; center of gravity is at 28.3 percent mean aerodynamic chord; rudder trim tab, 0.5° airplane nose left; airplane normal-force coefficient, 0.25.

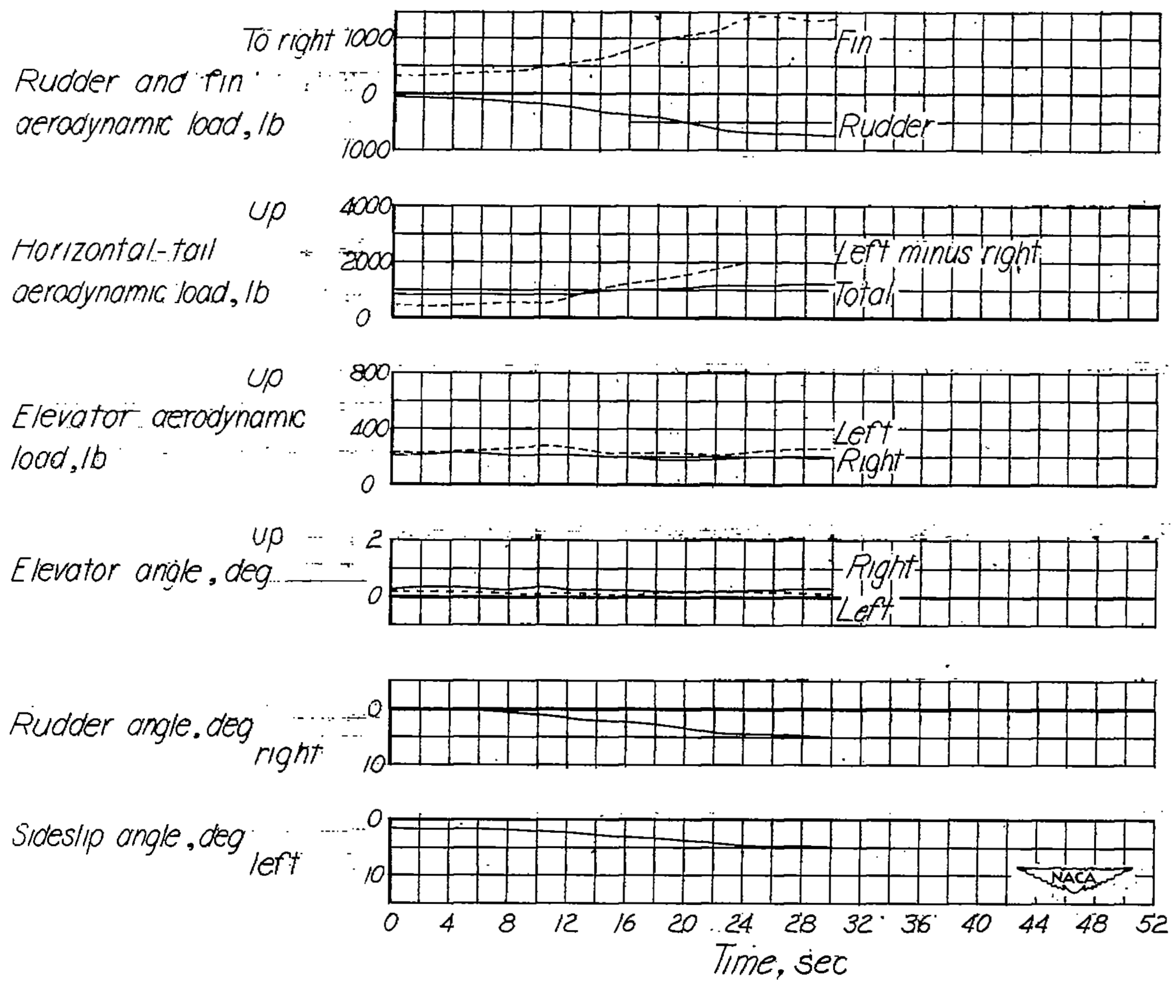

Figure 10.- Time histories of various quantities during a left sideslip. Pressure altitude, 20,300 feet; Mach number, 0.55; airplane weight, 62,100 pounds; center of gravity is at 28.3 percent mean aerodynamic chord; rudder trim tab, 0.5° airplane nose left; airplane normal-force coefficient, 0.25.

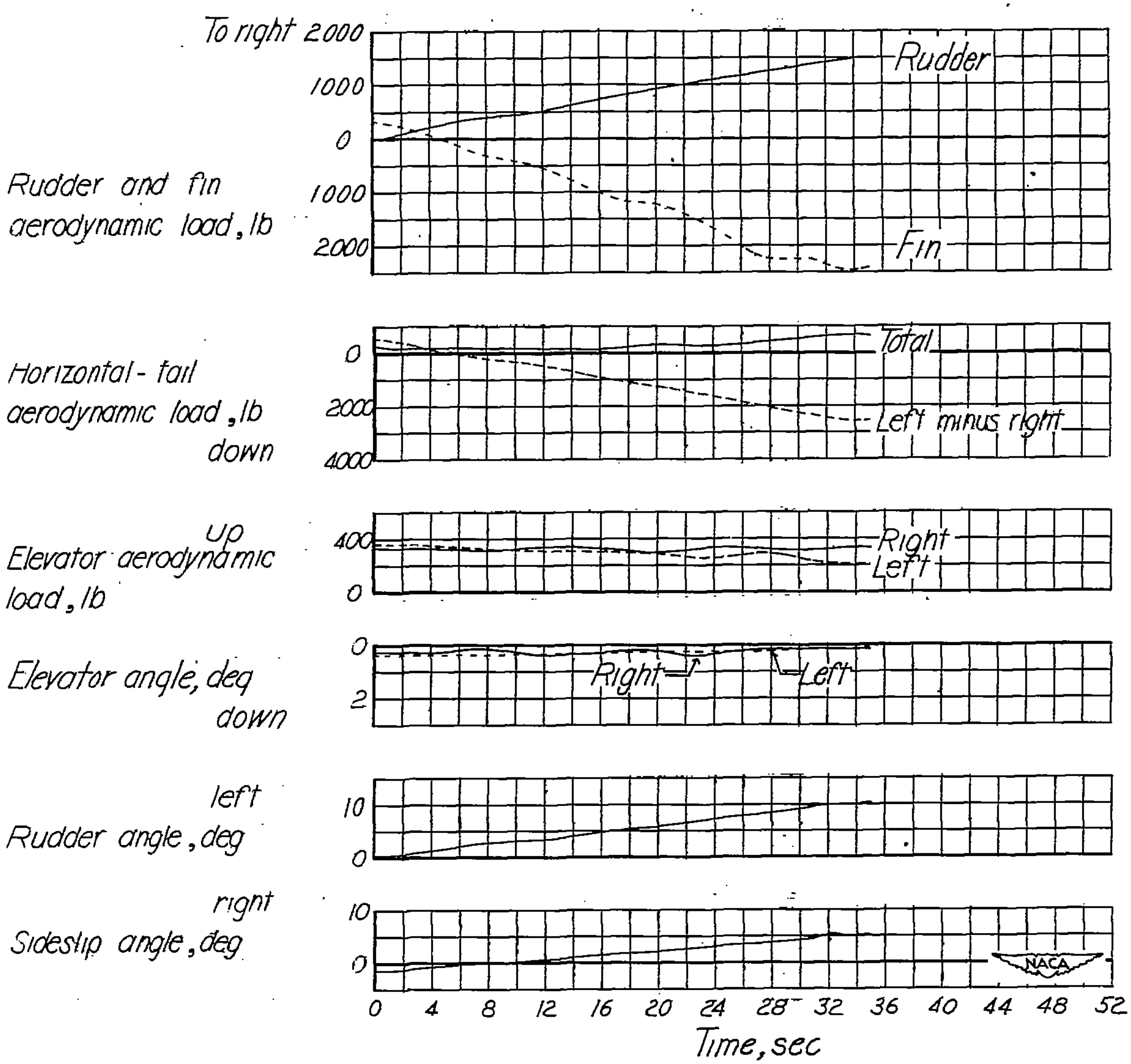

Figure 11.- Time histories of various quantities during a right sideslip. Pressure altitude, 20,100 feet; Mach number, 0.62; airplane weight, 61,600 pounds; center of gravity is at 28.2 percent mean aerodynamic chord; rudder trim tab, 0° airplane nose left; airplane normal-force coefficient, 0.20.

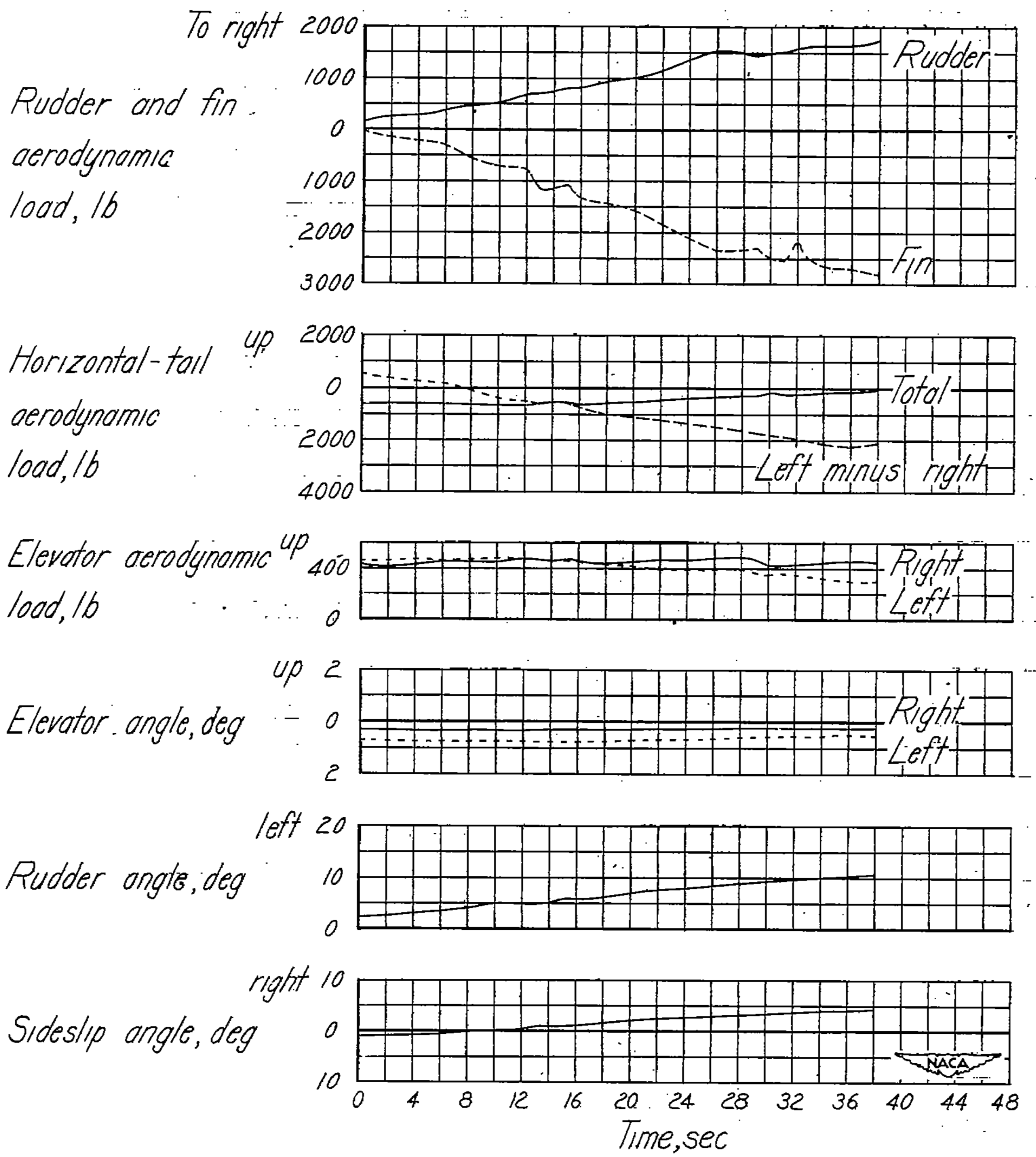

Figure 12.- Time histories of various quantities during a right sideslip. Pressure altitude, 20,200 feet; Mach number, 0.67; airplane weight, 62,300 pounds; center of gravity is at 28.0 percent mean aerodynamic chord; rudder trim tab, 0.5° airplane nose left; airplane normal-force coefficient, 0.17.

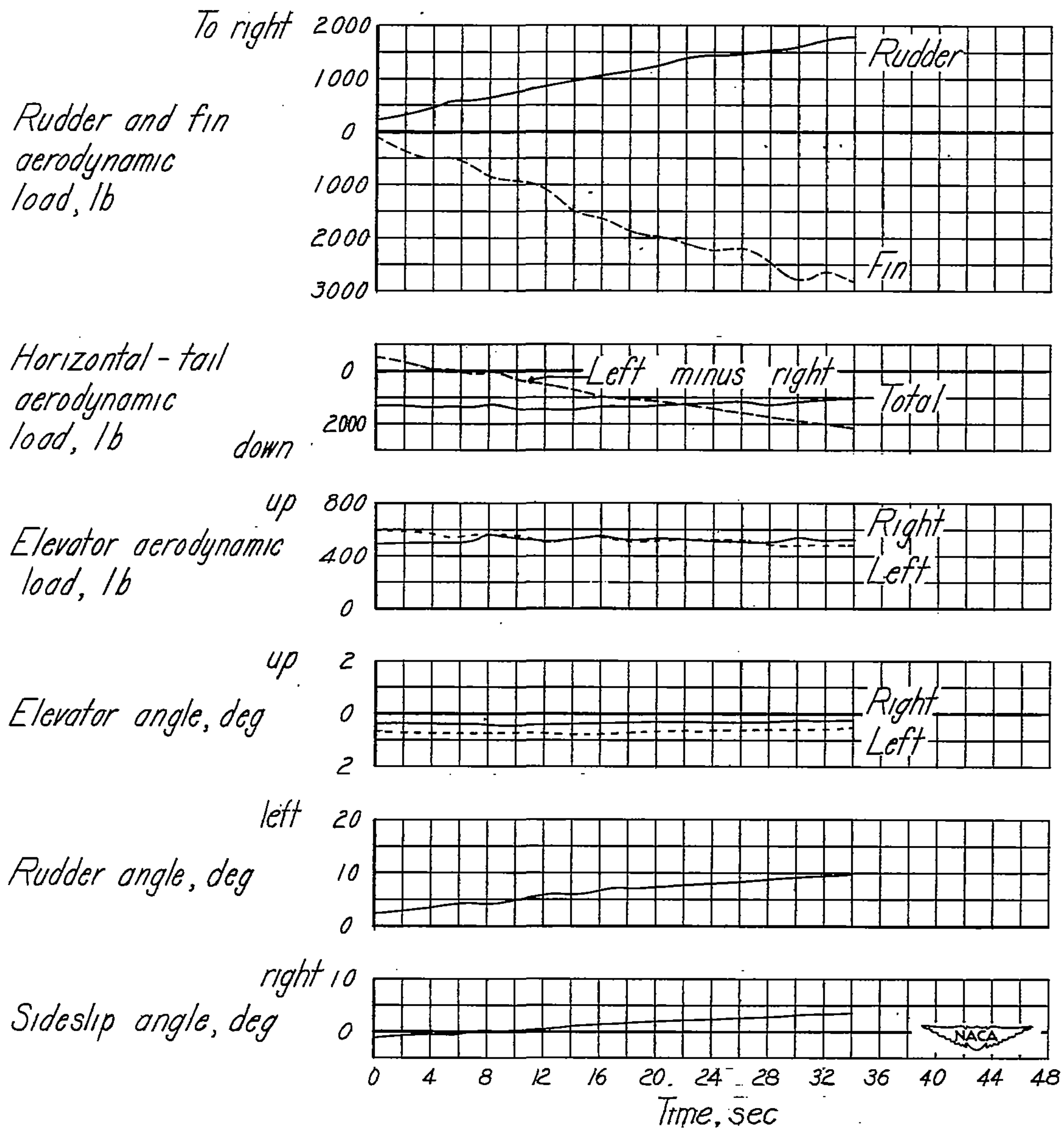

Figure 13.- Time histories of various quantities during a right sideslip. Pressure altitude, 19,600 feet; Mach number, 0.70; airplane weight, 62,000 pounds; center of gravity is at 27.9 percent mean aerodynamic chord; rudder trim tab, 0.5° airplane nose left; airplane normal-force coefficient, 0.15.

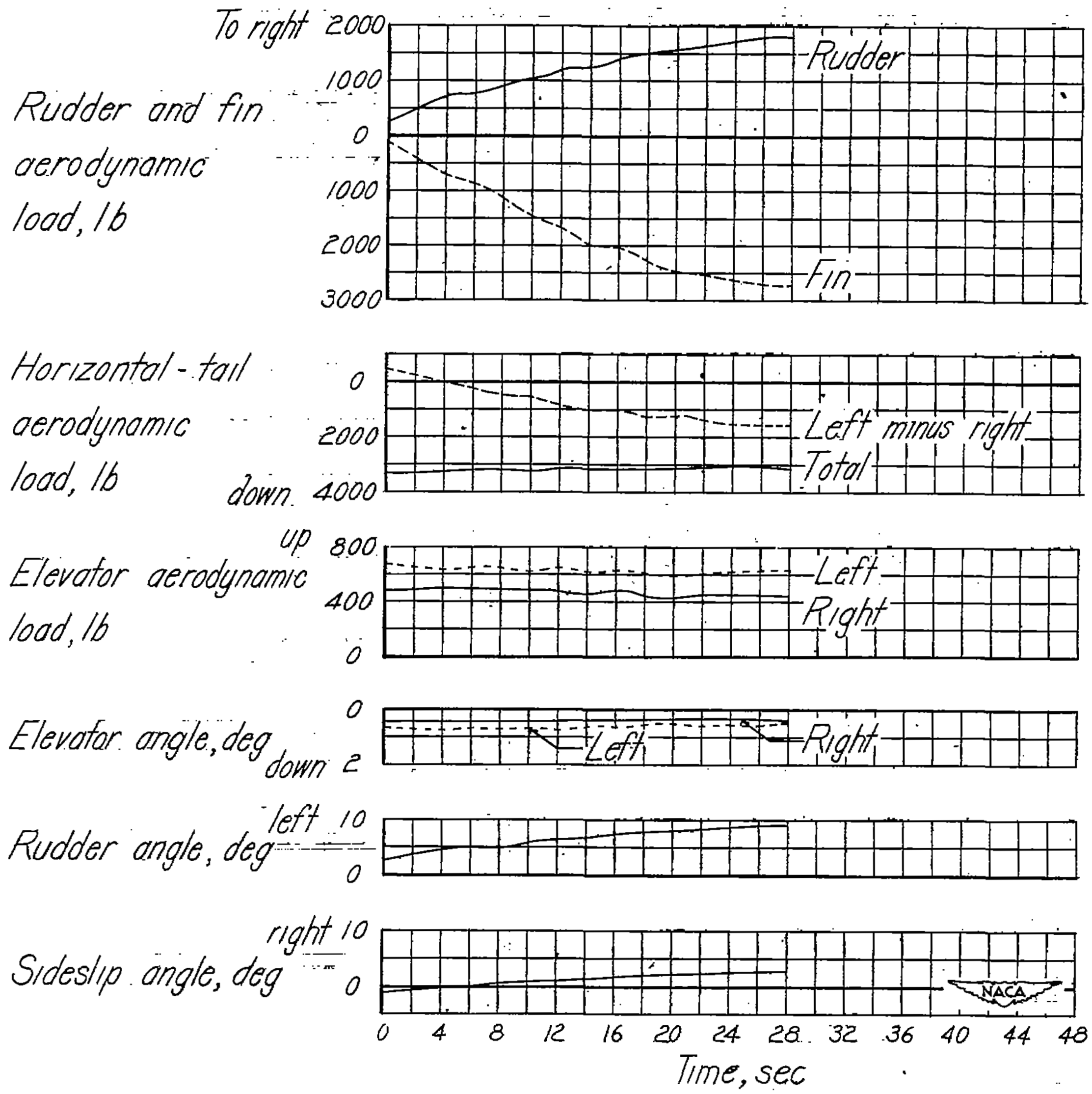

Figure 14.- Time histories of various quantities during a right sideslip. Pressure altitude, 19,400 feet; Mach number, 0.74; airplane weight, 61,000 pounds; center of gravity is at 27.8 percent mean aerodynamic chord; rudder trim tab, 0.5° airplane nose left; airplane normal-force coefficient, 0.13.

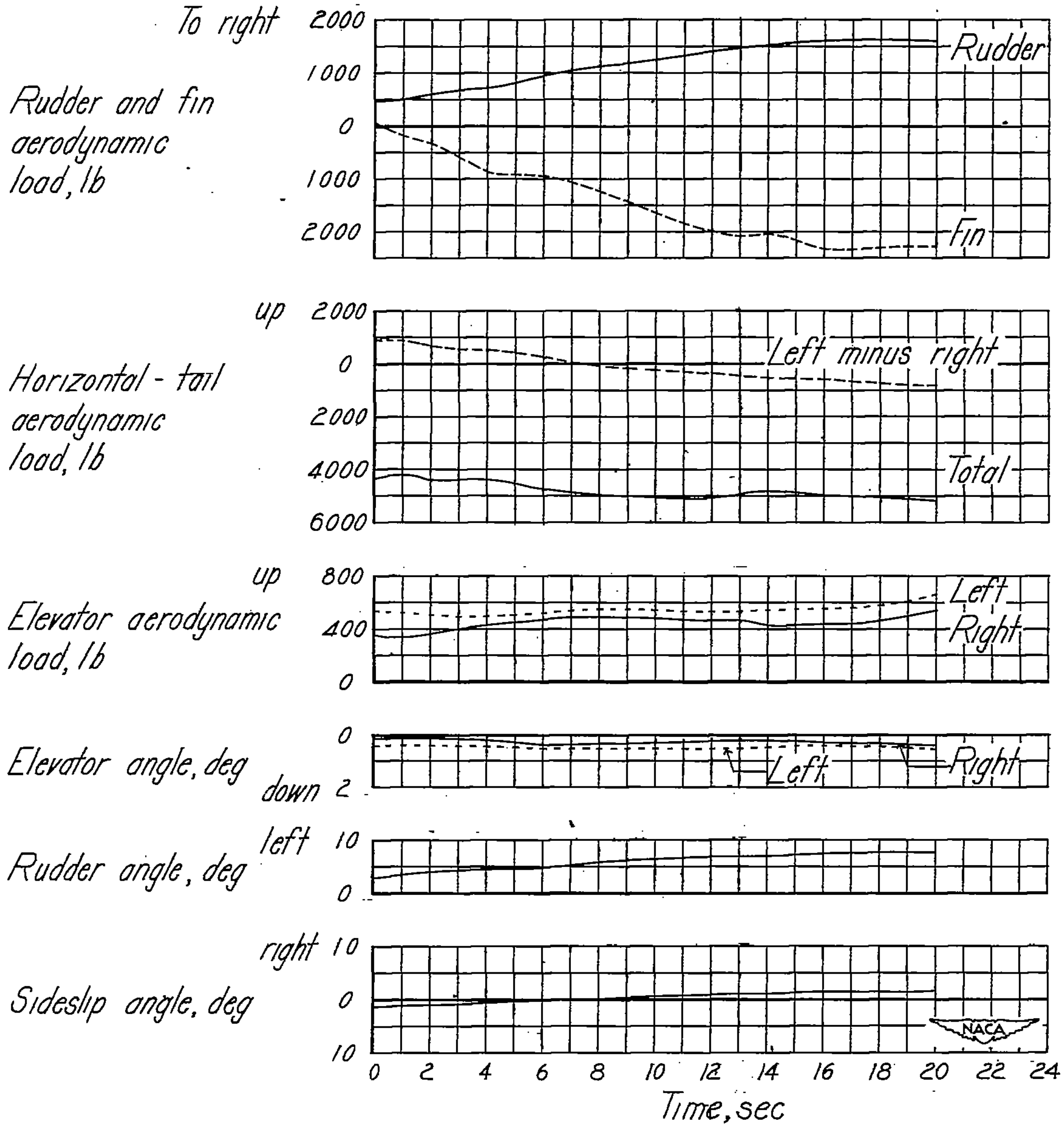

Figure 15.- Time histories of various quantities during a right sideslip. Pressure altitude, 18,200 feet; Mach number, 0.76; airplane weight, 60,500 pounds; center of gravity is at 27.7 percent mean aerodynamic chord; rudder trim tab, 0.5° airplane nose left; airplane normal-force coefficient, 0.12.

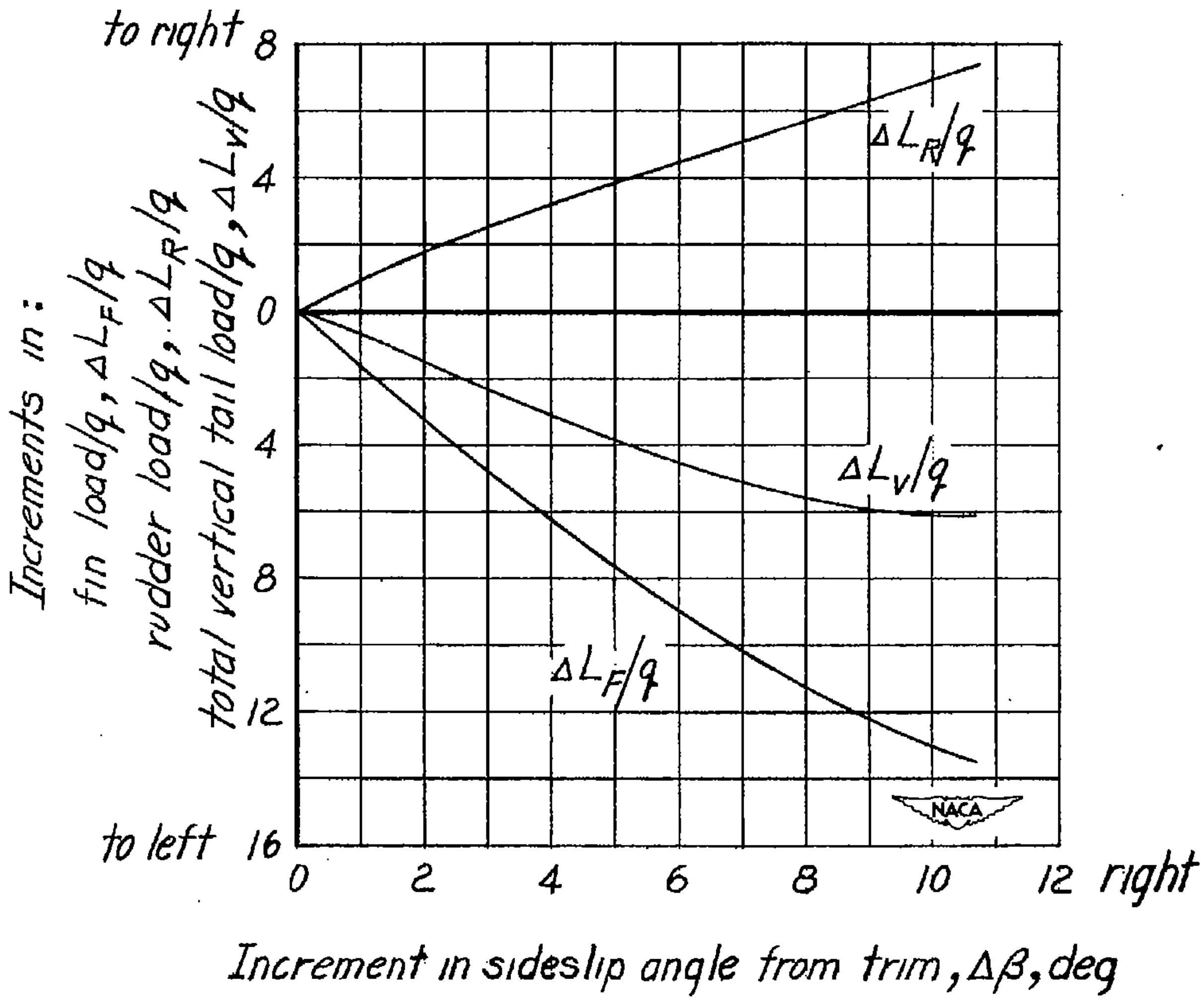

Figure 16.- Variation with sideslip of incremental fin, rudder, and total vertical-tail loads per unit dynamic pressure. Pressure altitude approximately 20,000 feet; Mach number, 0.45; airplane normal-force coefficient, 0.39.

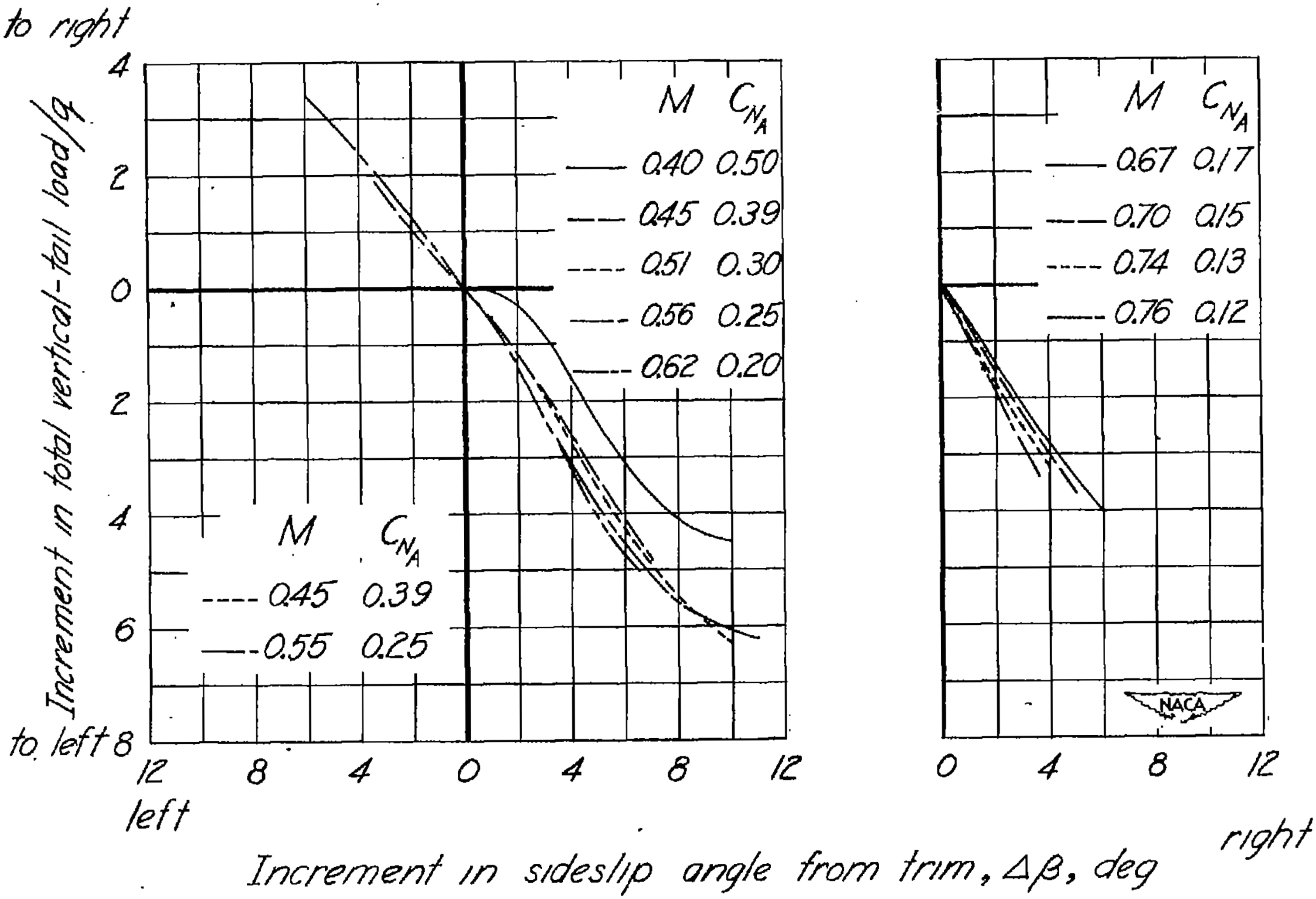

Figure 17.- Variation with sideslip of the incremental total vertical-tail load per unit dynamic pressure at approximately 20,000 feet altitude.

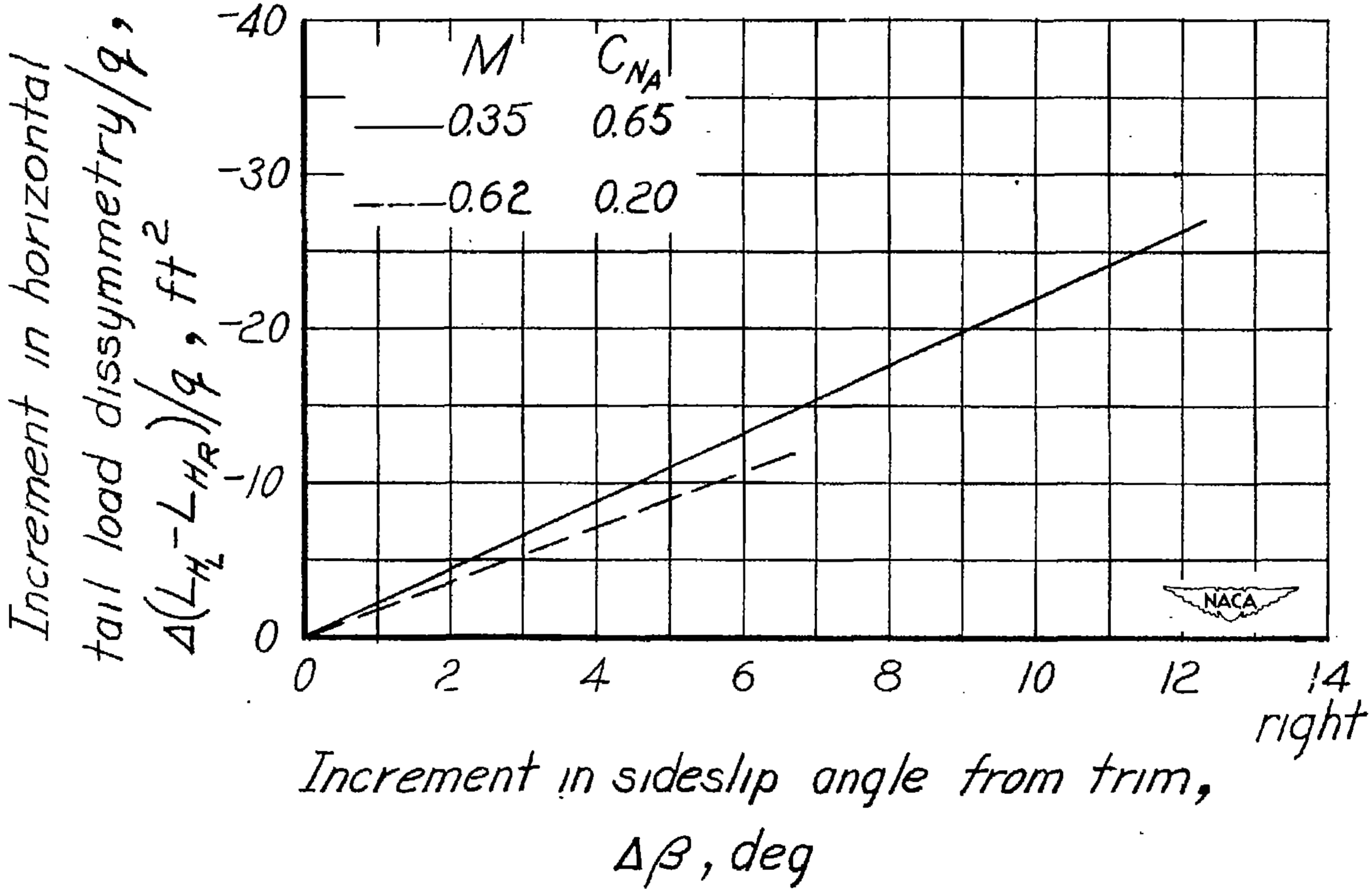

Figure 18.- Variation with sideslip of the incremental horizontal-tail-load dissymmetry per unit dynamic pressure at approximately 20,000 feet altitude.

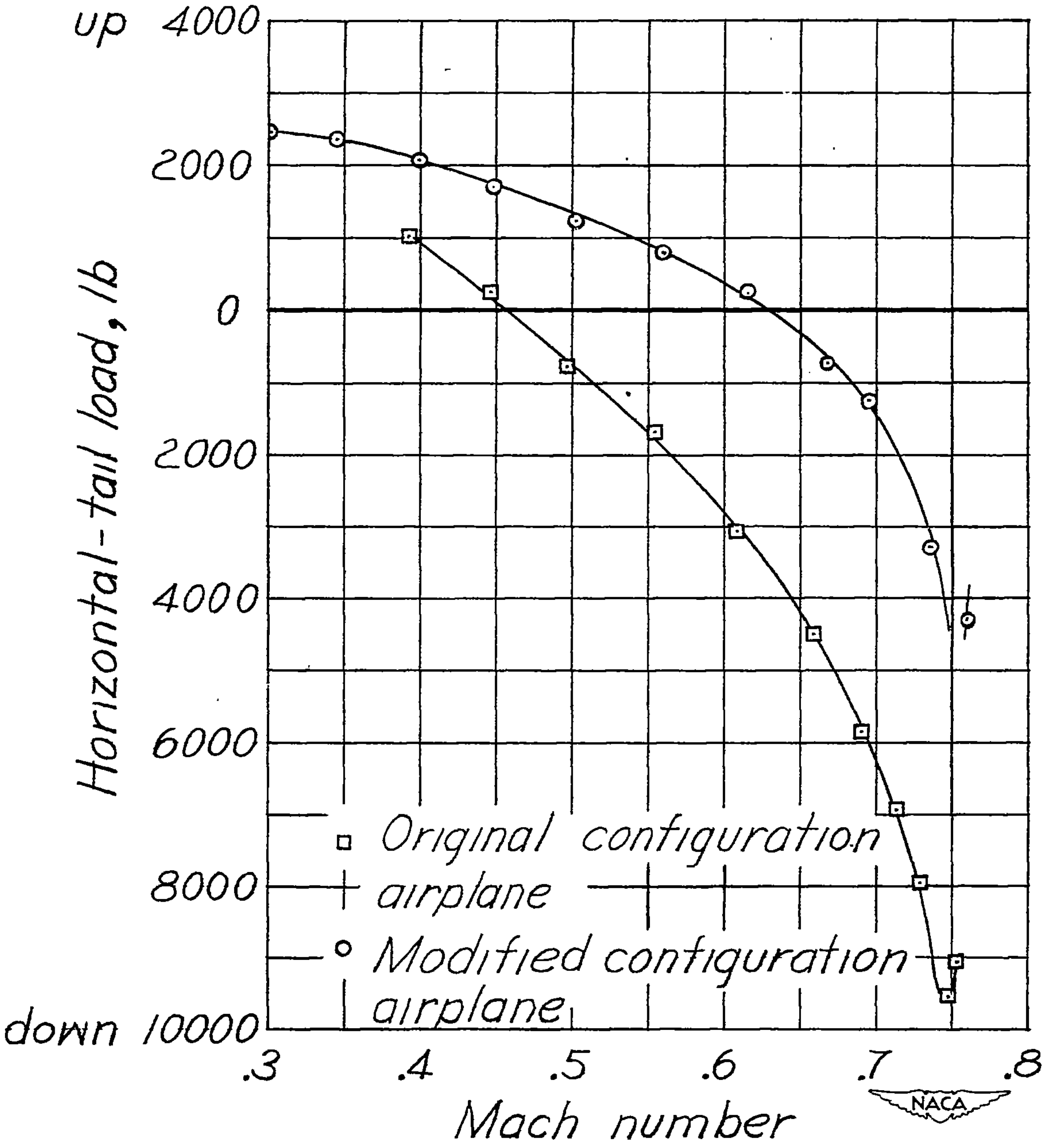

Figure 19.- Variation of horizontal-tail load with Mach number. 1g level flight conditions at approximately 20,000 feet altitude.

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